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CHARACTERIZATION OF DNAPL SOURCE ZONE ARCHITECTURE IN CLAY TILL AND LIMESTONE BEDROCK BY INNOVATIVE AND CURRENT SITE INVESTIGATION TECHNIQUES

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Characterization of dense non-aqueous phase liquid (DNAPL) source zone architecture is essential to develop accurate site specific conceptual models, delineate and quantify contaminant mass, perform risk assessment, and select and design remediation alternatives. The activities of a distribution facility for perchloroethene (PCE) and trichloroethene (TCE) at the Naverland site near Copenhagen, Denmark, has resulted in PCE and TCE DNAPL impacts to a fractured clay till and an underlying fractured limestone aquifer/bedrock. A range of innovative and current site investigative tools for direct and indirect documentation and/or evaluation of DNAPL presence were combined in a multiple lines of evidence approach. The scope of the investigations was to evaluate innovative investigation methods and characterize the source zone hydrogeology and contamination to obtain an improved conceptual understanding of DNAPL source zone architecture in clay till and bryozoan limestone bedrock.

Surface investigations included Ground Penetrating Radar (GPR) and seismic reflection and refraction. Investigations in the clay till included membrane interface probing (MIP) with FID, ECD and GC-MS analysis; coring with discrete subsampling for quantitative analysis, SudanIV hydrophobic colour test, colour spray test, PID and geologic descriptions; NAPL and FACT FLUTe exposure and discrete FACT subsampling and analysis; liquid sampling from boreholes; and a radon and PCE/TCE soil gas survey. Investigations in the limestone aquifer included coring with discrete subsampling for quantitative analysis, SudanIV hydrophobic colour test, PID and geologic descriptions; NAPL and FACT FLUTe exposure and discrete FACT subsampling and analysis; FLUTe liner hydraulic conductivity profiling; Water-FLUTe installation and multilevel groundwater sampling for quantitative analysis under two flow conditions .

Though no single technique was sufficient for characterization of DNAPL source zone architecture, the combined use of MIP; coring with quantitative subsample analysis, SudanIV test, and PID; and NAPL FACT FLUTe gave good insight in the source zone architecture in the clayey till. Surface geophysics with GPR and seismic combined with geologic information supplemented the conceptual understanding of transport and distribution of DNAPL in the fill and clayey till and the interface to the limestone. Core loss in the limestone, particulary from soft zones in contact with flint beds, was caused by the water flush applied during drilling and likely also resulted in loss of DNAPL from high permeability features. Hence, coring and subsampling for quantitative analysis and SudanIV tests continues to be an unresolved challenge in limestone. The coring may also have impacted DNAPL in high permeability zones near the borehole, thereby, potentially affecting the use of the NAPL FLUTe. Water-FLUTe multilevel groundwater monitoring and sampling (under two flow conditions) and FACT-FLUTe sampling and analysis provided important information regarding potential presence of DNAPL versus dissolved and sorbed phase contamination in the limestone matrix. These combined methods provided an improved conceptual understanding of DNAPL source zone architecture in fractured limestone. It is expected that down-hole logs, cross-borehole geophysical methods, and flow and solute transport modeling can supplement the conceptual understanding of DNAPL distribution in limestone aquifers.

The DNAPL source zone characterization showed DNAPL at the fill-clay till interface, vertical migration through fractures in the upper part of the clay till, horizontal migration along fractures and/or other high permeability features around the redox transition zone in the clay till, and then continued vertical migration through fractures to the underlying sand and limestone. This is consistent with conceptual expectations based on contaminant distribution at other clay till sites. For the limestone aquifer the results indicate horizontal spreading in the upper crushed zone, vertical migration through fractures in the bryozoan limestone down to about 16-18 depth with some horizontal migration along horizontal fractures within the limestone. In conclusion, the documentation for and quantification of DNAPL in the limestone aquifer is limited and demands refinement of current and innovative techniques and further characterization.

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